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RESEARCH MEMORANDUM

A STUDY OF THE USE OF LEADING-EDGE NOTCHES AS A MEANS FOR IMPROVING THE LOW-SPEED PITCHING-MOMENT CHARACTERISTICS OF A THIN 45° SWEPT WING OF ASPECT RATIO 4

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A STUDY OF THE USE OF LEADING-EDGE NOTCHES AS A MEANS FOR IMPROVING THE LOW-SPEED PITCHING-MOMENT CHARACTERISTICS OF A THIN 45° SWEPT WING OF ASPECT RATIO 4

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SUMMARY

In an effort to develop a simple but effective means for controlling the stall progression of swept wings, a low-speed investigation has been undertaken primarily to determine the effectiveness of leading-edge notches. The investigation included consideration of notch size, location, and shape, as well as combined effects of notch—chord-extension and notch-fence arrangements. The wing used in the study had 45° quarter-chord sweep, aspect ratio 4, taper ratio 0.3, and NACA 65A006 airfoil sections streamwise.

The results of the investigation indicated that although substantial improvements were obtained in the wing pitching-moment characteristics at moderate angles of attack, by use of outboard leading-edge notches, none of these notches produced desirable wing stability characteristics throughout the angle-of-attack range. The wing pitching-moment characteristics were relatively insensitive to notch size and to small changes in spanwise location. The use of a notch at the inboard end of a chord-extension increased the effectiveness of the chord-extension near stall and produced the same results as a chord-extension having an equivalent inboard overhang. Small localized notch—chord-extension combinations were found to produce the same pitching-moment characteristics as much larger chord-extension configurations. A leading-edge root cutout used in conjunction with a small outboard notch—chord-extension combination resulted in fairly desirable overall wing pitching-moment characteristics.

INTRODUCTION

In several previous investigations systematic studies have been made of various means for improving the longitudinal stability characteristics of a wing-fuselage combination having a 45° swept wing of aspect ratio 4 (see, for example, refs. 1 to 3). These investigations, which were made at both low and high subsonic speeds, considered such items as fences, chord-extensions, and leading-edge droop.

In a continuing effort to develop new and perhaps more effective means of improving the longitudinal stability of the aforementioned swept-wing configuration, a low-speed investigation was undertaken primarily to determine the effectiveness of leading-edge flow-control notches which have been developed fairly recently. The operation of the notch (see fig. 1) seems to be somewhat similar to that of a chord-extension in that the vortex shed from the outboard edge of the notch opposes the motion of the leading-edge vortex, thereby altering the stall progression in such a manner as to improve the wing pitching-moment characteristics. Further information relative to the use of notches can be found in references 4 to 6.

The purpose of this investigation was to determine the effect of leading-edge notches (used either independently or in conjunction with other devices) on the low-speed aerodynamic characteristics of a 45° swept wing. The investigation included consideration of notch size, location, and shape, as well as combined effects of notch—chord-extension and notch-fence arrangements.

SYMBOLS

C_L lift coefficient, Lift/qS

C_D drag coefficient, Drag/qS

C_m pitching-moment coefficient referred to $0.25\bar{c}$, Pitching moment/$qS\bar{c}$

S wing area (neglecting cutouts), sq ft

$\bar{c}$ mean aerodynamic chord of wing, $\frac{2}{S}\int_0^{b/2} c^2 dy$, ft

c local wing chord, parallel to plane of symmetry, ft

b	wing span, ft
y	spanwise distance from plane of symmetry, ft
q	effective dynamic pressure, $\rho V^2/2$, lb/sq ft
ρ	air density, slugs/cu ft
V	free-stream velocity, ft/sec
α	angle of attack of wing chord line, deg

MODEL

The basic wing had a quarter-chord sweepback of 45°, aspect ratio of 4, taper ratio of 0.3, and NACA 65A006 airfoil sections parallel to the free stream.

A drawing of the wing showing the geometry of the various notches, chord-extensions, and fence configurations used in the present investigation is presented as figure 1. The leading edge of the notches was maintained uncambered with a radius slightly greater than that of the basic airfoil section. The chord-extensions were fabricated of sheet metal in such a manner as to maintain as closely as possible the original contour of the wing nose sections.

TESTS AND CORRECTIONS

The model was tested on the single-strut support in the Langley 300 MPH 7- by 10-foot tunnel at a Mach number of about 0.17, which corresponds to a Reynolds number of about 1.62×10^6 based on the mean aerodynamic chord of the wing for average test conditions. Tests were made through an angle-of-attack range from about -4° to 30°.

The angle-of-attack and drag data of this model were corrected for jet-boundary effects by the method of reference 7. The jet-boundary correction to the pitching moment was negligible and therefore was not applied. Corrections for vertical bouyancy on the support strut and for longitudinal pressure gradient have been applied. Corrections for the tare forces and moments produced by the support sturt have not been applied. Although these effects might alter the absolute values of the coefficients somewhat, the relative effects of the modifications investigated are believed to be valid.

RESULTS AND DISCUSSION

Effect of notch configuration.- The effects of notch location and geometry are summarized in figures 2 to 5. The data indicate that none of the notch configurations were instrumental in producing desirable wing pitching-moment characteristics throughout the angle-of-attack range although substantial improvements in the stability were obtained at moderate angles of attack. The effectiveness of a 5-percent-chord notch (2 percent semispan in width) was increased at moderate angle of attack as the notch center line was moved inboard from 69 to 56 percent semispan. At α greater than about 16° the notch lost effectiveness and the notched-wing stability was worse than that of the basic wing. (See fig. 2.) Increasing the spanwise extent of the gap from 2 to 5 percent of the semispan (fig. 3) did not alter the stability characteristics. Other results (unpublished) have indicated that the notch effectiveness is fairly well maintained with a gap of 1 percent semispan and even a slit of one-fifth of 1 percent semispan had a small favorable effect. Increasing the depth of the 5-percent-wide notch from 5 to 10 percent of the local chord resulted in slightly poorer stability characteristics below stall but reduced the pitch-up tendency at the stall.

It is seen from figure 4 that the use of multiple notches did not result in any further gains over that obtained with a single notch. Moreover, the configuration with all three notches open resulted in the loss of most of the notch effectiveness.

It was felt that sharpening the outboard edge of the notch might increase the strength of the vortex shed from this side and thus improve the notch effectiveness. The experimental data (fig. 5), however, showed no improvement in stability characteristics attributable to the sharpened side.

The effect of notch configuration on the lift and drag characteristics was generally of little consequence.

Notch-fence combinations.- The effect of leading-edge fences used in conjunction with a 0.05c notch at the 0.63b/2 to 0.65b/2 station is shown in figure 6.

The small fence, F_1, used alone had somewhat less effect than the notch in delaying the unstable tendency near stall. The use of fence, F_1, as an endplate for the inboard or outboard side of the notch resulted in substantially the same stability characteristics as obtained for the notch alone. (See fig. 6.) The use of fence, F_2, which extended around the leading edge just outboard of the notch delayed the occurrence of the pronounced instability to about $\alpha = 20^{\circ}$.

Notch-chord extension combinations.- A comparison of the relative effects of chord-extensions and notches (which seem to operate on essentially the same aerodynamic principle) and combinations thereof is presented in figures 7 and 8.

Either device showed about the same effectiveness in reducing the unstable tendency at moderate angles of attack ($\alpha = 8^{\circ}$ to 17°). (See fig. 7.) A $0.05\bar{c}$ chord-extension from $0.65b/2$ to the wing tip retained effectiveness to about 2° higher angle than a 0.05c notch extending from $0.63b/2$ to $65b/2$. A $0.05\bar{c}$ chord-extension combined with a 0.05c notch produced essentially the same pitching-moment curve as a $0.10\bar{c}$ chord-extension; whereas a 0.05c notch added to the $0.10\bar{c}$ extension gave the best overall stability characteristics.

The data of figure 8 illustrate the manner in which the effectiveness of a small tapered chord-extension can be increased near stall by notching. The C_m characteristics of the small tapered chord-extension used in conjunction with the $0.10\bar{c}$ notch were almost identical to the results obtained with the best configuration obtained in figure 7. Both arrangements had approximately $0.15\bar{c}$ discontinuity at the 0.65 semispan station.

From these results it would appear desirable to have the outboard edge of the wing discontinuity project slightly forward; however, once this is done, more or less equivalent gains in effectiveness can be obtained from either a notch or larger chord-extension.

The incorporation of a $0.10b/2$ leading-edge root cutout (modification A, fig. 9) in combination with the best outboard "fix" of figure 8 improved the stability characteristics of the wing at moderate angles of attack and resulted in fairly desirable overall wing pitching-moment characteristics. The large root cutout had little effect on the lift characteristics below stall, but produced a somewhat greater loss of lift beyond stall than the wing with the outboard fix alone. (See fig. 9.) The addition of small root notches (modification B) to the configuration with the outboard fix resulted in little change in pitching-moment characteristics.

Effect of large fences.- A large full-chord fence located at $0.65b/2$ and used in an effort to isolate effectively the tip sections of the swept wing produced desirable C_m characteristics up to about $\alpha = 12^{\circ}$. (See fig. 10.) At higher angles of attack the large fence was about as effective as some of the chord-extension configurations in improving the stability characteristics. A large fence located on the upper surface of the wing near the tip resulted in essentially no change in the C_m characteristics of the basic wing.

CONCLUSIONS

The results of an investigation made primarily to investigate the effect of leading-edge notches on the low-speed pitching-moment characteristics of a thin 45° swept wing of aspect ratio 4 indicated that:

1. Although substantial improvements were obtained in the wing pitching-moment characteristics at moderate angles of attack by use of outboard leading-edge notches, none of these notches produced desirable wing stability characteristics throughout the angle-of-attack range.

2. The wing pitching-moment characteristics were relatively insensitive to notch size and to small changes in spanwise notch location. The effect of notch configuration on the lift and drag characteristics was generally of little consequence.

3. The use of a notch at the inboard end of a chord-extension increased the effectiveness of the chord-extension at high angles of attack and produced the same results as a chord-extension having an equivalent inboard overhang.

4. Small localized notch—chord-extension combinations were found to produce the same pitching-moment characteristics as much larger and structurally less desirable chord-extension configurations.

5. A leading-edge root cutout used in conjunction with a small outboard leading-edge notch—chord-extension combination resulted in fairly desirable overall wing pitching-moment characteristics.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 14, 1953.

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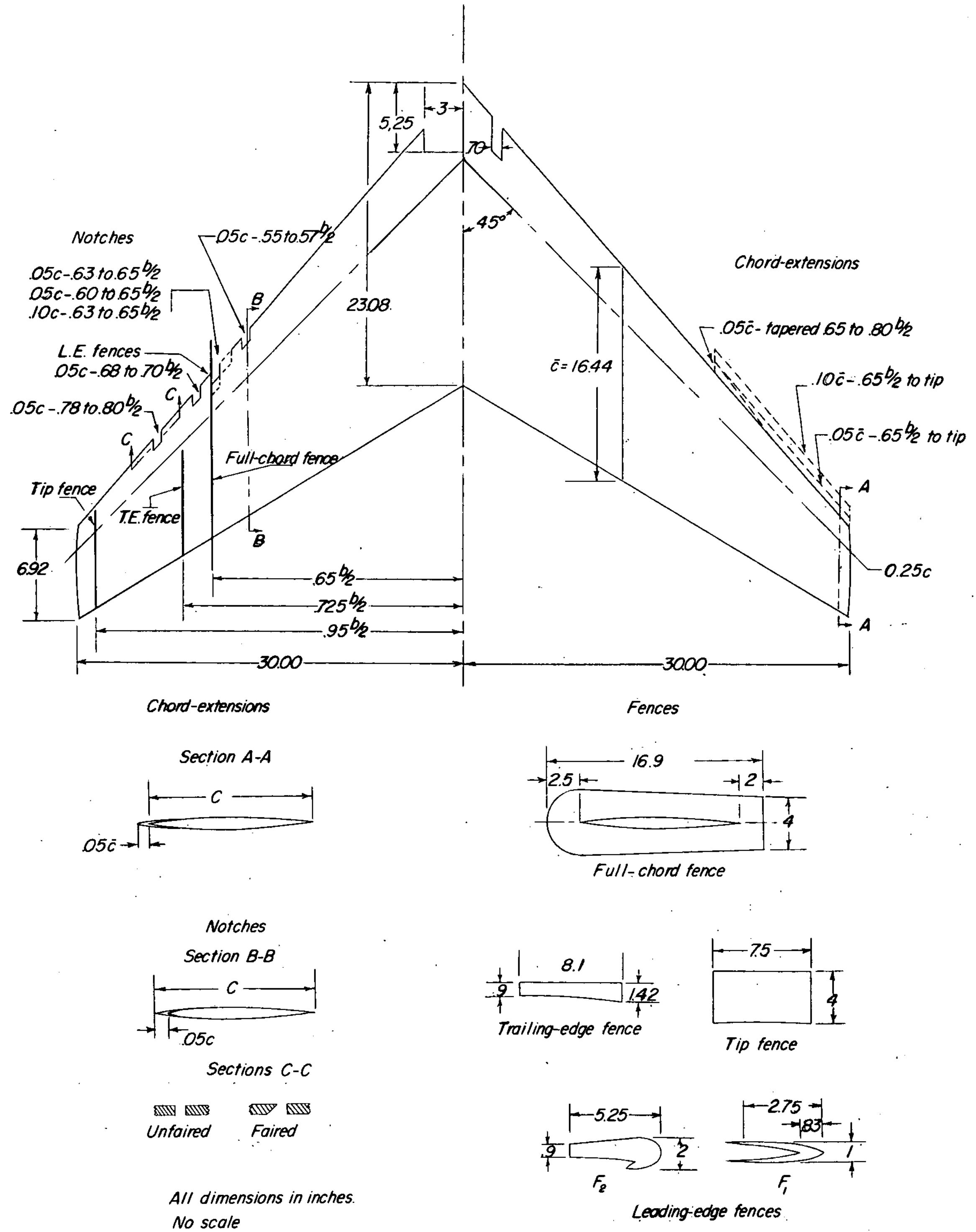

Figure 1.- Details of notches, chord-extensions, and fences investigated.

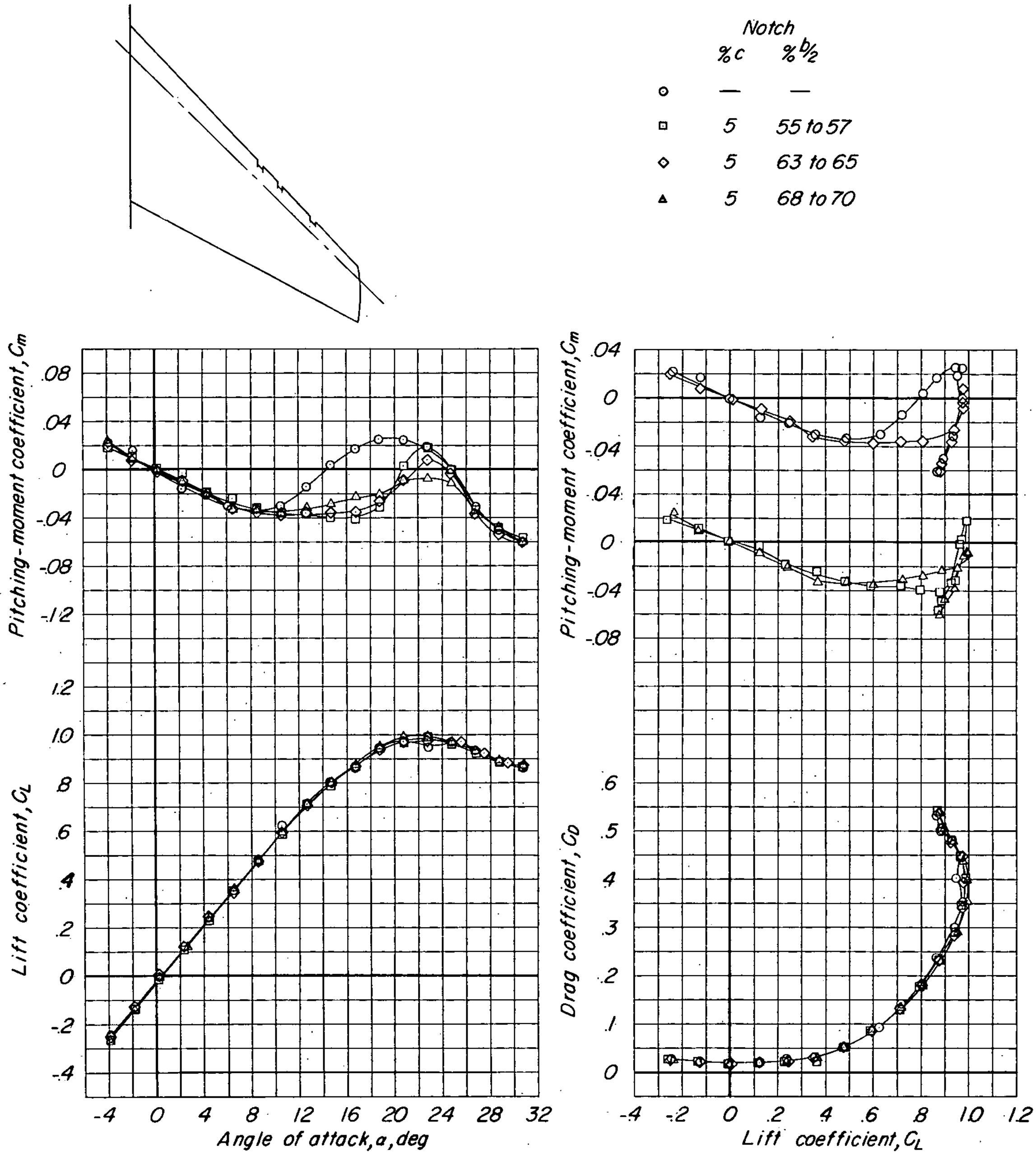

Figure 2.- Effect of notch spanwise location.

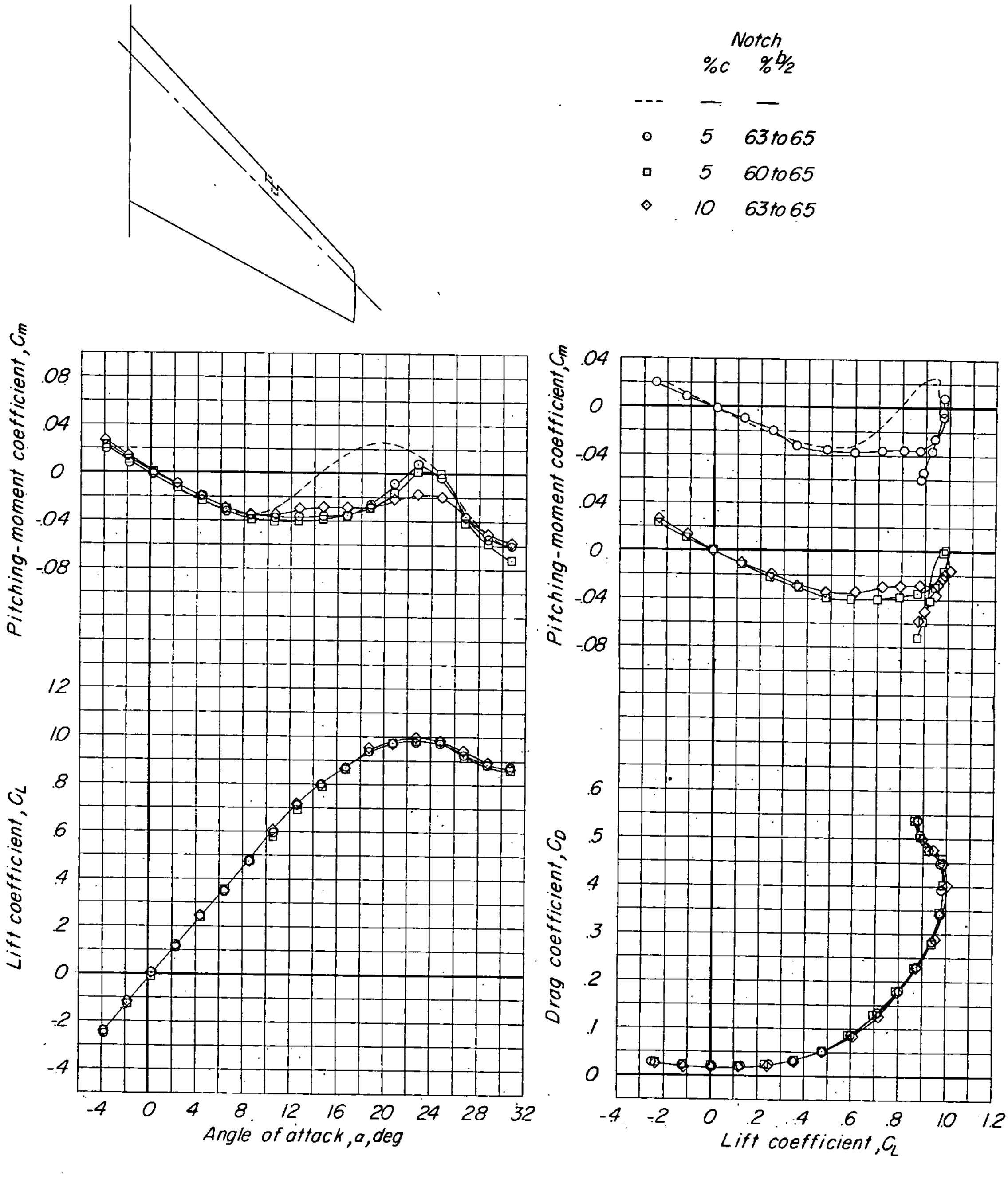

Figure 3.- Effect of notch size.

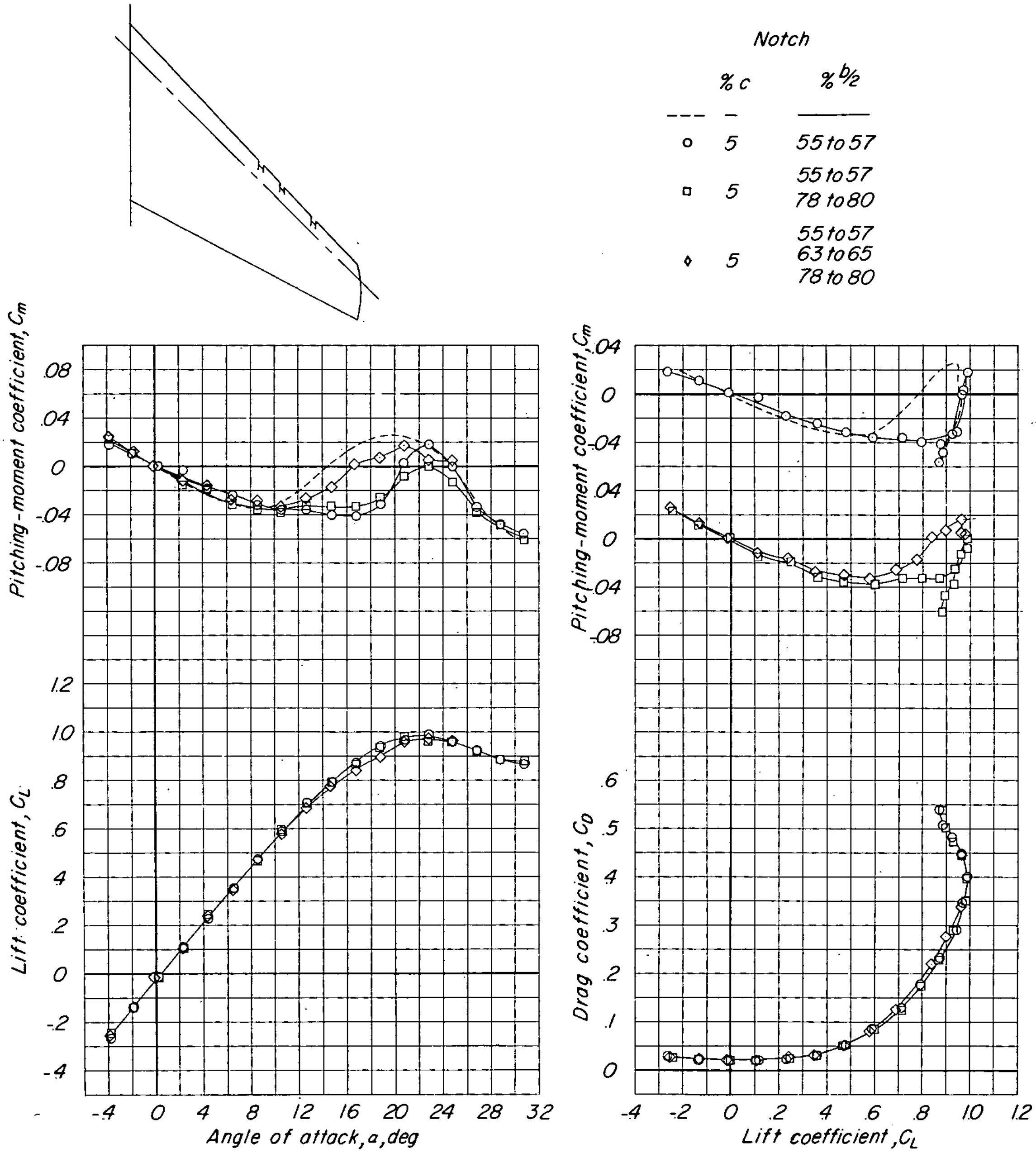

Figure 4.- Effect of multiple notches.

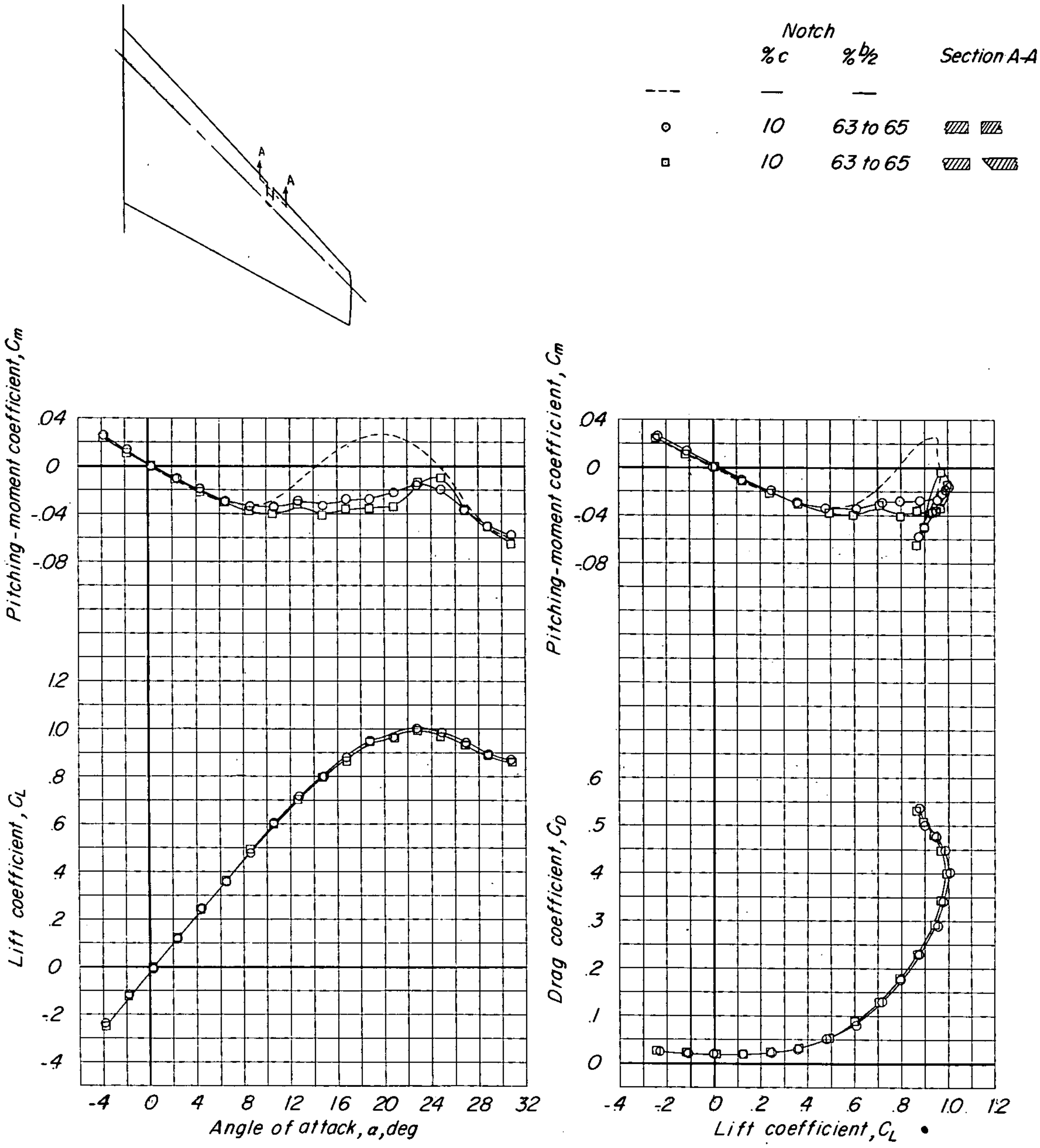

Figure 5.- Effect of notch edge shape.

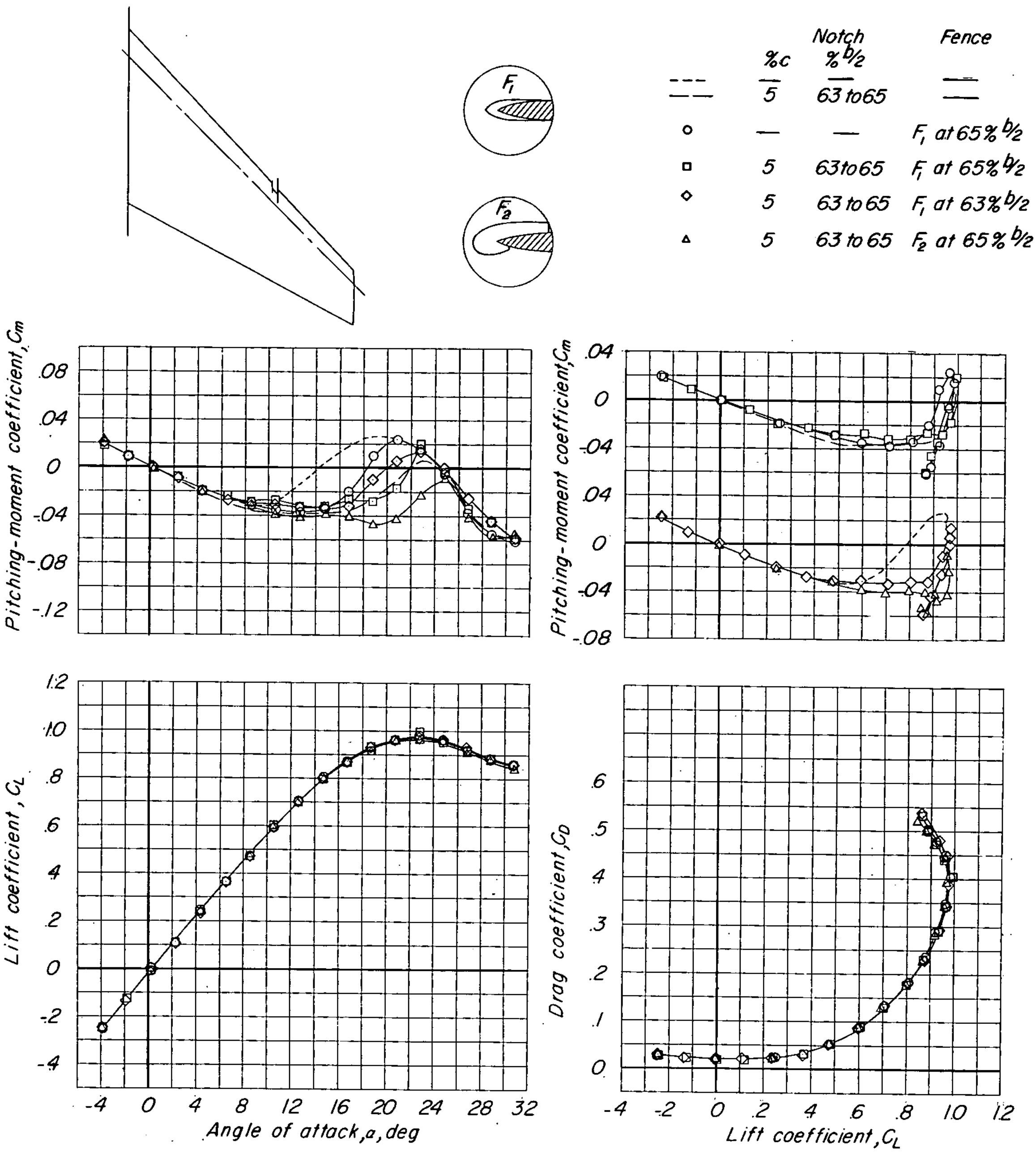

Figure 6.- Notch-fence combinations.

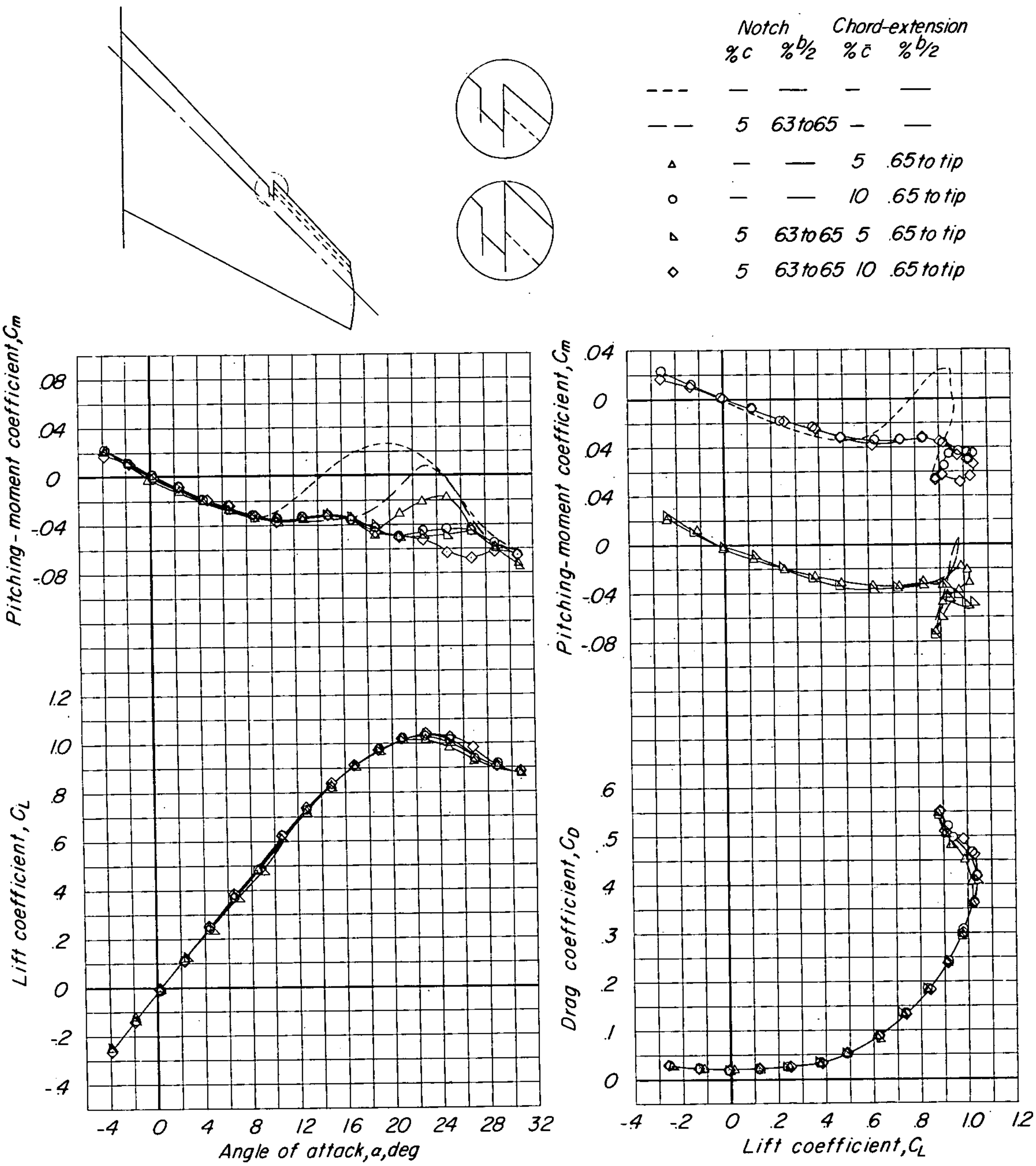

Figure 7.- Notch—chord-extension combinations.

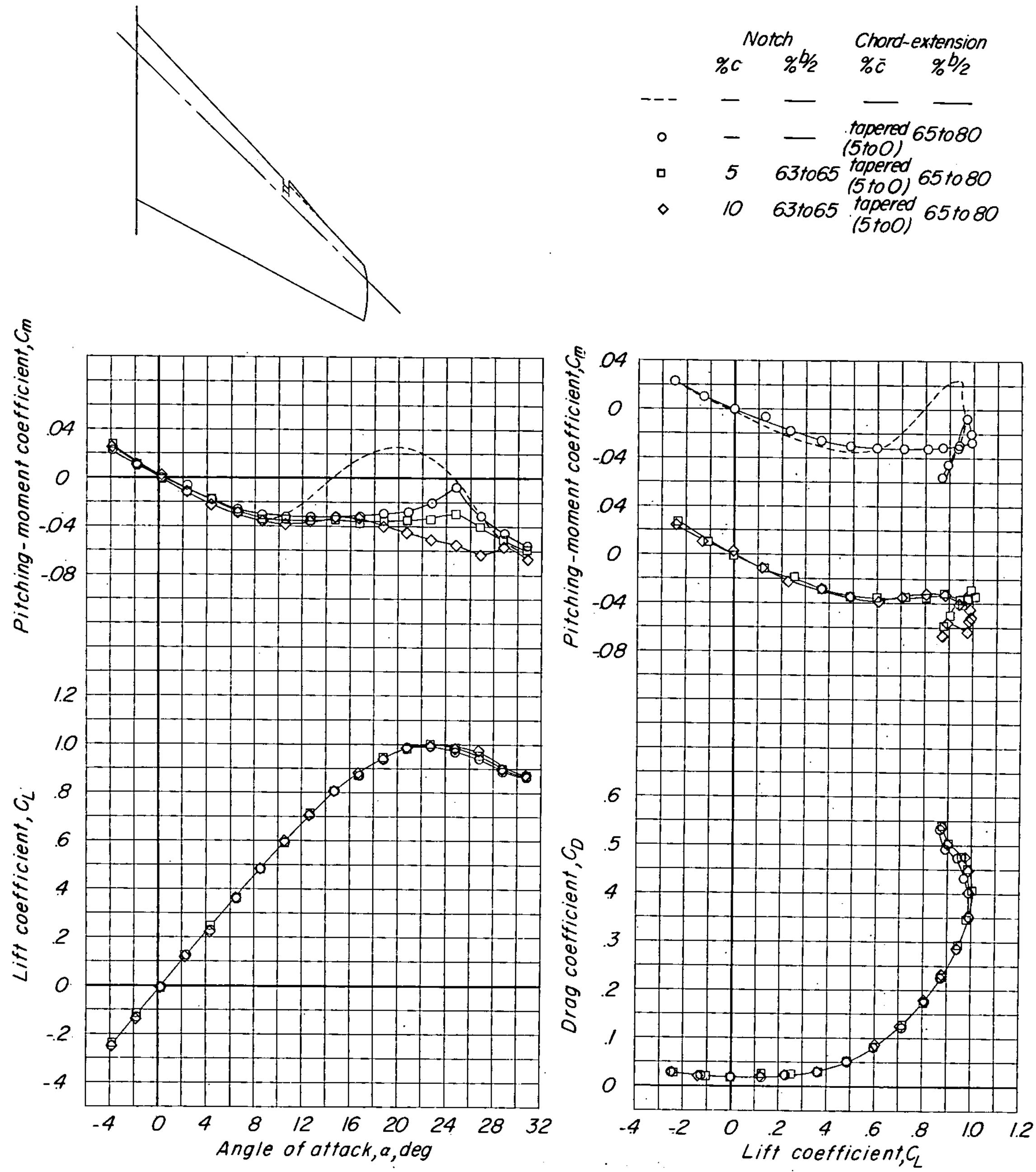

Figure 8.- Effect of notching inboard end of tapered partial-span chord-extension.

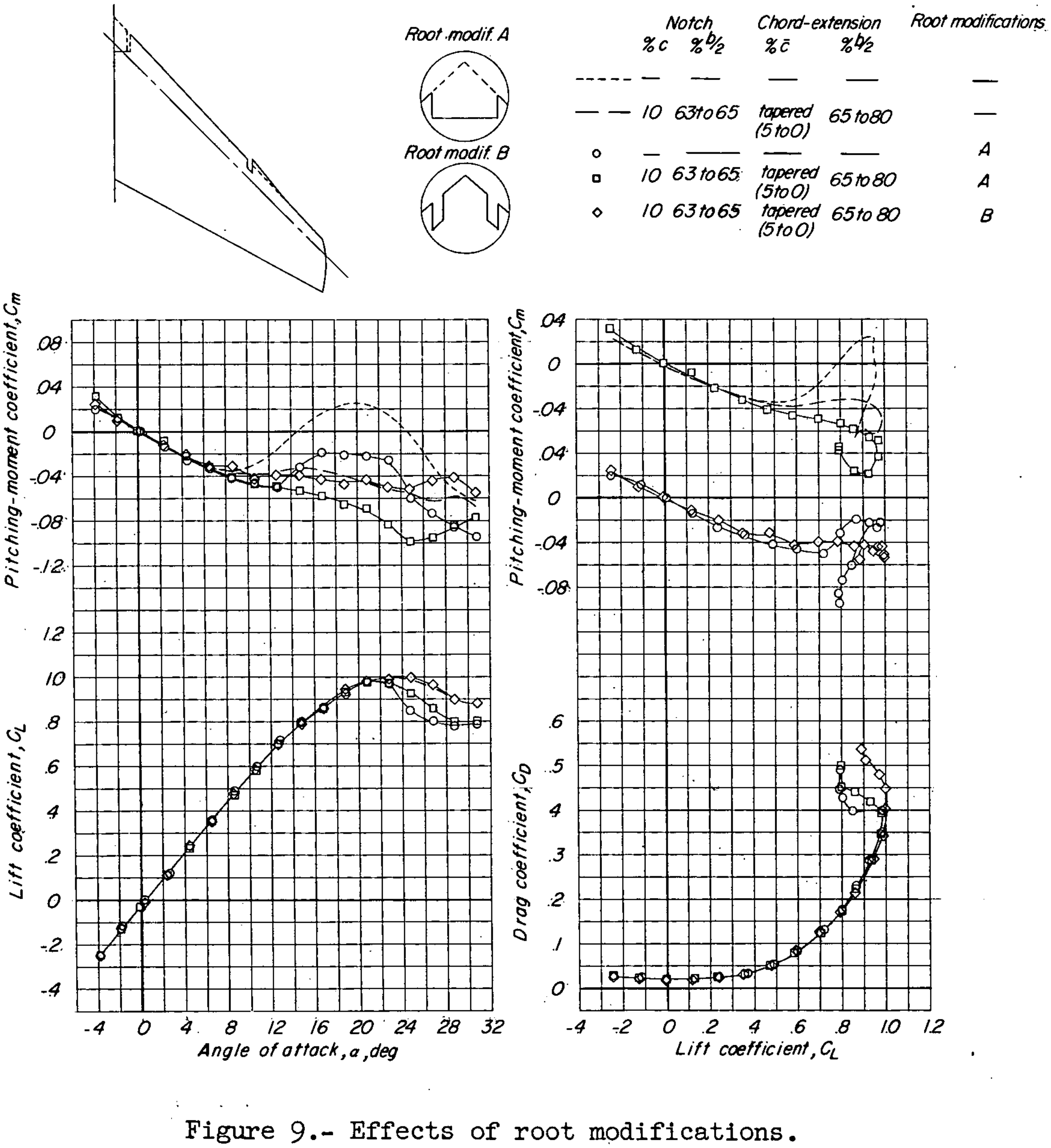

Figure 9.- Effects of root modifications.

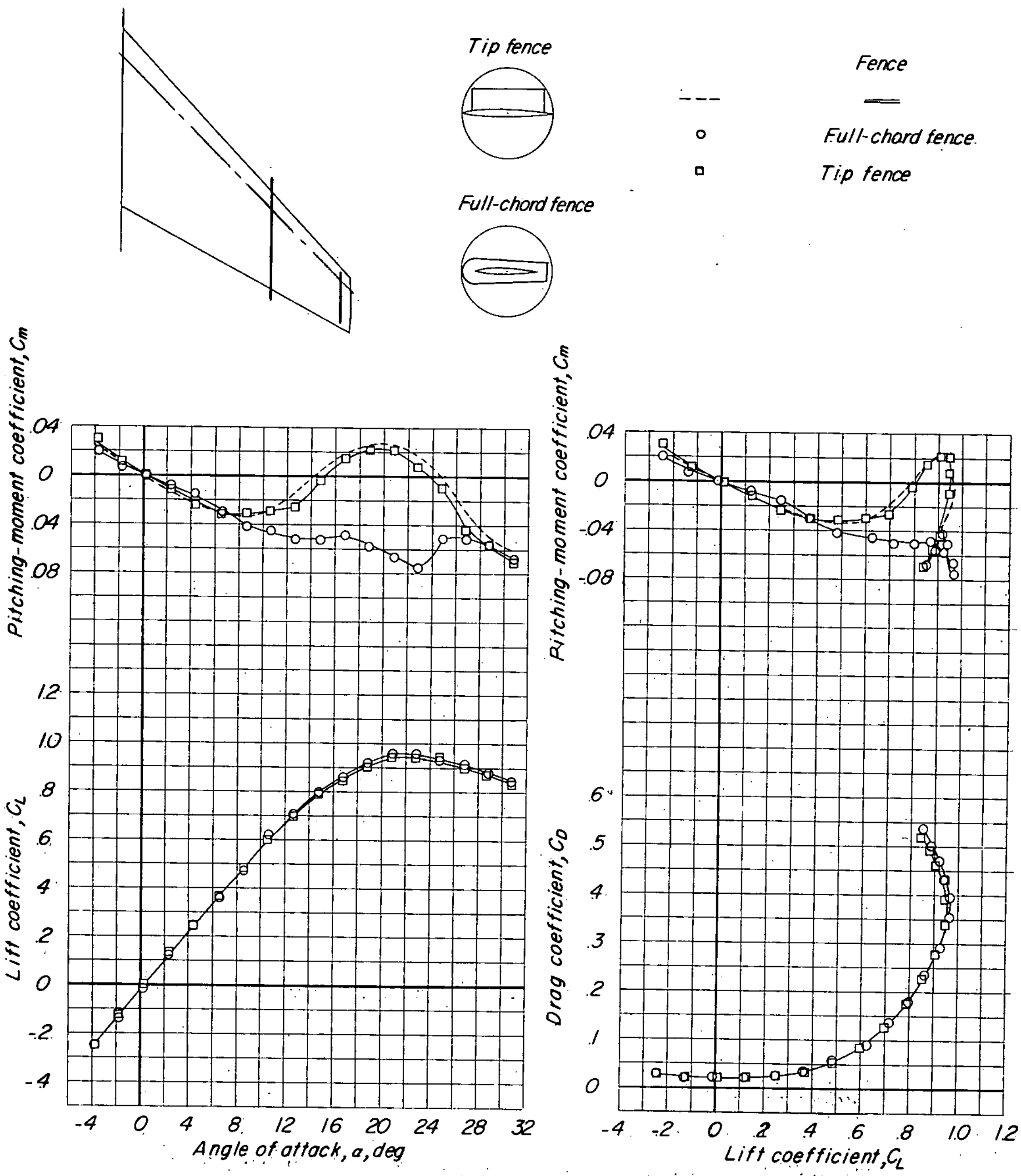

Figure 10.- Effect of large fences.

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